Briefing

FRIENDS of the earth
for the planet for people

January 2000

Greenhouse Gases and Waste Management Options

Introduction

Enough municipal waste is produced each year in England and Wales to cover the entire area of Hyde Park to a depth of 80 feet - 27 million tonnes in 97/98[1]. Disposal of this waste is a major industry which costs money, wastes resources and damages the environment. Currently only eight per cent of municipal waste is recycled, and the vast bulk (85%) is simply dumped in landfill sites[1]. But increasing pollution control and a shortage of landfill space means that there is growing pressure for alternative disposal methods.

The threat of climate change has focussed attention on greenhouse gas production from waste disposal. The available studies show that recycling is a better option in terms of greenhouse gas emissions than incineration (even with energy recovery), and that for some materials landfilling is a better option than incineration. Incineration actually INCREASES greenhouse gas emissions as compared with recycling because destroying materials through burning means that we then have to use more energy overall to extract and process raw materials into the goods that we buy and use.

A US model of greenhouse gas emissions, which, if applied to components of the UK waste stream, estimates that recycling and composting household waste might save up to 4.5 million tonnes of carbon emissions (as the greenhouse gas carbon dioxide) per year as compared with an alternative scenario of incineration with energy recovery. This would be equivalent to the emissions generated by 55 billion kilometres of vehicle travel in the UK - some 12% of all vehicle kilometres.

A large part of this greenhouse gas (GHG) savings is attributed to paper recycling. There is considerable uncertainty about changes in forest growth and coverage, increasing carbon storage, when harvesting rates are reduced. But the notion that recycling of paper contributes to habitat protection and reduction of GHGs has been supported by the Intergovernmental Panel on Climate Change, which has stated[2]:

> *"Paper recycling is another strategy with the potential to reduce harvest levels [of timber] and promote greater carbon conservation."*

This paper considers the impact of incineration on the overall greenhouse gas (GHG) releases through the life cycle of a number of materials which form a considerable part of household waste.

Energy from waste?

When waste is burnt in an incinerator, heat is produced which can be used to produce electricity or for direct heating purposes. This displaces the need for an equivalent amount of electricity to be generated at a power station, saving the release of some carbon dioxide, a greenhouse gas (*see Box 1*), from fossil fuel power stations[3]. Proponents of "energy from waste" schemes (EFW) are promoting this type of waste disposal as "renewable energy"[4]. Recycling itself actually uses energy, much of it supplied by fossil fuel power generation, so at first glance it might seem that EFW could be advantageous and the best option for dealing with waste. But a more thorough consideration of the energy and greenhouse gas emissions through the entire life cycle of products and waste shows that this is a superficial conclusion

Or a waste of energy?

The crucial factor that puts recycling ahead of incineration or landfill is that recycling a material uses far less energy than the extraction and processing of virgin materials. Creating a tonne of aluminium cans from raw bauxite takes around 5 times as much energy as producing a tonne of recycled aluminium cans[5]. Aluminium is a particularly favourable example, but various studies have shown that much less energy is extracted by burning than is needed to replace the products from scratch for most materials. A Canadian study *(see table 1)* estimated that[6]

> "*[on] average, ...recycling saves three to five times as much energy as is produced by incinerating municipal solid waste*".

In energy terms, recycling of most materials gives a huge advantage. So capturing the materials in waste is actually more productive than merely capturing the energy.

Greenhouse Gases

However consumption of energy and greenhouse gas emissions are not necessarily the same thing: it is possible to generate energy without releasing greenhouse gases, and different fuels have different output of energy per unit of GHGs released. For

Material	**Relative energy needed for manufacture versus energy generated from EFW incineration**
Newspaper	2.6 times
Office paper	4.3 times
Glass containers	30 times
Tin cans	30 times
Aluminium cans	350 times
Plastic	3 - 5 times
Textiles	5 - 8 times

Table 1. Energy savings of recycling. *The ratio of energy conserved by substituting secondary for virgin raw materials in manufacture as compared with the amounts of energy yielded by EFW incineration (based on 15% efficiency). Although new incinerators might be expected to have a higher efficiency of energy capture and conversion (around 20%), the figures would still be similar (adapted from Ref 6).*

example, a wind farm produces energy without combustion of fossil fuel; or burning biofuel (eg wood) should have no net emissions if the biomass is harvested at the same rate as it regrows and is a truly sustainable process, although in practice there will almost undoubtedly be other related emissions (eg fuel used to chop down trees, in the manufacture of a wind turbine etc). Industrial processes (eg to produce paper or to recycle material) may use a variety of fuels - use of biofuel and fossil fuels, and activities such as transport and waste disposal may be significant.

The complexity of the processes means that some careful accounting has to be one to produce a true comparison of different waste management options in terms of greenhouse gases. Landfill (some with schemes to capture the methane generated), incineration with energy recovery, and recycling have to be considered along with the greenhouse gases involved in production (including transport emissions) of new or recycled materials.

To do a full accounting of the releases and avoided releases of GHGs, several stages have to be taken into account.

Box 1: Which gases have a greenhouse effect?

For consideration of different waste management options, the following gases are the most relevant:

- Carbon dioxide - formed when any material containing carbon is burned.
- Methane - formed when material containing carbon decomposes in the absence of oxygen, as in a landfill site. Relative to carbon dioxide, methane is 21 times more potent as a greenhouse gas than CO_2 over a 100-year time span (56 times over a 20-year period).
- Perfluorocarbons - released during primary aluminium production, and so important when disposal of aluminium cans is considered. Although released in small quantities, perfluorocarbons are thousands of times more potent than carbon dioxide.
- Nitrous oxide - some are produced during fossil fuel and waste combustion (other sources are less relevant for the comparison of waste disposal options). Nitrous oxide is 310 times more potent than carbon dioxide as a GHG.

For ease of comparison, releases of GHGs can be converted into "carbon dioxide equivalents" or "carbon equivalents" (the latter remove the weight of the oxide part). So one tonne of nitrous oxide has the same impact as 310 tonnes of carbon dioxide (or 84 tonnes of "carbon equivalents").

Box 2: Energy from waste - incineration

The heat that is generated when material is burnt can be put to use - to generate electricity power and to provide heat directly to homes or other buildings. If the two energy recovery systems are available, the plant is often referred to as a "Combined Heat and Power" (CHP) plant. Energy produced at an incinerator displaces coal-burning power and so saves on some GHG emissions at that point.

Electricity generation at incinerators is only about 20% efficient, which means that only one-fifth of the original material's energy content is captured and turned into electricity. If "waste" heat is put to use as well, then the efficiency could theoretically rise to 60% - 75% [1]. However, not all CHP plants are able to sell their heat - for instance, a planned district heating system at the SELCHP incinerator in London (South East London Combined Heat and Power) is not set up years after opening the incinerator. And even with a system in place, heat can be less easy to sell in the summer, so in practice nothing like the maximum theoretical efficiency may be achieved. In the UK the amount of heat reclaimed is very small compared with the electricity generated[7].

Electricity generation should be viewed as a side-line to the waste disposal effort, rather than as a useful part of energy generation. Energy recovery makes waste disposal more profitable or more competitive, but for reasons given in this briefing, we do not view it as a renewable energy source.

Greenhouse gases are:

- released during power generation by fossil fuel plants
- released in extraction and processing of raw materials and during manufacture of a new virgin product (including during transport)
- released during manufacture using recycled materials
- released during transport of recyclables or waste to its destination
- released by burning waste
- released in landfill gases from a landfill site
- saved by generation of electricity or heat from incineration or burning of landfill gas (as compared with coal fired power generation, the marginal fuel in England and Wales)
- saved by long-term storage ("sequestration") of carbon (eg in plastics) in a landfill site;
- saved by long-term storage (or increased rate of storage of carbon) in plant growth (eg trees).

Life Cycle Studies

Not all studies comparing the environmental impact of various options take into account the entire life cycle and replacement of lost materials[9]. But this is a crucial part of the equation.

The most comprehensive attempt at cataloguing the relative GHG emissions is a US Environmental Protection Agency report published in 1998[5]. Although there are uncertainties about some of the exact figures, and the US EPA is still refining the model[10], it is worth noting that a draft was published for review by all interested parties before its final release - which means that the waste disposal industry, the American Forest and Paper Association and others have had ample opportunity to comment on the figures.

This study analysed several different waste streams in terms of greenhouse gas emissions over the entire life cycle including taking into account displaced fossil fuel emissions from energy generation. Emissions of greenhouse gases were estimated as significantly less for recycling than for landfill or incineration for the following categories of waste materials - newspaper, office paper, corrugated card, aluminium cans, steel cans, and various types of plastic (high density polyethylene, low density polyethylene and polyethylene teraphthalate (PET)). Only food waste had lower emissions if incinerated - due to their renewable nature and the fact that they contribute to energy generation in an EFW incinerator.

The study also compared landfill to incineration with respect to greenhouse gas emissions. In some cases (newspaper and plastics), overall emissions were estimated to be less for landfill, reflecting the assumption that a considerable amount of carbon is stored in the landfill and not broken down.

The report makes a very strong case for recycling. Overall, for a tonne of mixed recyclable material, EFW incineration is estimated to save only 0.22 tonnes of carbon emissions as compared with landfill, whilst recycling could save 0.87 tonnes of carbon emissions per tonne. Thus incinerating waste results in more greenhouse gas emissions than does recycling, even taking into account generation of energy from waste.

It is also worth noting that transport distances have very little influence on the overall picture *(see Table 3)*. The EPA report estimated that emissions from transportation of waste are a very small fraction compared with the emissions for the process manufacturing[4].

Paper Recycling in the UK

There has been a lot of debate about the desirability of recycling paper. It is well accepted that recycling paper takes less energy overall than the manufacture of virgin paper[13,14]. But recycling uses some fossil fuel energy whilst virgin pulp manufacture uses a high proportion of biofuels (such as waste bark)[15]. In addition, volatile and low market prices for waste paper have probably reinforced the notion in some minds that recycling is undesirable.

One of the main paper recyclers in Britain is the Aylesford mill in Kent. A study undertaken for Aylesford Newsprint Limited used detailed figures provided by the recycling mill in a comparison against paper production by a number of other mills[7]. This study is thus very specific to the particular mill, but showed that producing one tonne of recycled newsprint released 11% less carbon emissions than producing

Tonnes of carbon saved (metric tonnes of carbon equivalents) per tonne of waste

	Recycling vs landfill	EFW incineration vs landfill	Recycling vs incineration
Mixed MSW		0.02	
Mixed recyclables	0.87	0.22	0.65
Newspaper	0.69	-0.01	0.70
Office paper	1.48	0.79	0.69
Corrugated card	0.81	0.25	0.56
Aluminium cans	4.28	-0.02	4.30
Steel cans	0.64	0.54	0.10
High density polyethylene	0.42	-0.22	0.64
Low density polyethylene	0.55	-0.23	0.78
PET	0.69	-0.24	0.93
Food scraps (composting)	0.16	0.22	-0.06
Yard waste (composting)	-0.12	-0.04	0.08

Table 2: Savings in greenhouse gas emissions (US data) - comparisons of waste management options. *A positive number represents a net savings of greenhouse gas emissions for the first named option. Conversely, a negative number indicates a net increase in emissions as compared with the alternative. (Source: Ref 5, USEPA 1998)*

	GHG emissions saved (tonnes carbon equivalent per tonne of material)		
Material	Incineration: 32 km	Recycling: 32 km	Recycling: 320 km
Newspaper	-0.241	-0.944	-0.714
Mixed paper - residential	-0.211	-0.734	-0.684
Aluminium cans	0.030	-4.269	-4.049
Glass	0.027	-0.087	-0.028
PET plastic	0.313	-0.684	-0.384

Table 3: Changes in GHG emissions with distance to a recycling facility *The table shows that, as expected, GHG emissions increase if the distance to a recycling facility is increased (ten-fold here just for illustration). However the GHG savings are still much greater than for incineration locally. Figures were calculated using the US EPA "WARM" model (v 1.9).*

one tonne of alternatively sourced newsprint even if EFW incineration was accounted for in waste paper disposal. This amounted to savings of nearly 0.28 tonnes of carbon dioxide equivalents (0.08 tonnes of carbon equivalents) per tonne of paper over a 20-year period. This result is a considerably lower figure than found in the US study mentioned previously, but still gives recycling a GHG emission advantage as compared with incineration for these particular circumstances.

It is worth noting that old growth forest is still being harvested for paper pulp. This is a tragic destruction of rich and increasingly rare habitat, and should not be described as "sustainable" even if new trees are then planted. Reducing harvesting rates of wood generally would take some pressure off forests, decreasing or preferably eliminating the destruction of old growth forests. In Finland, where 95% of natural old growth forest has been converted to intensively managed secondary forest, conservationists argue that increased recycling should lead to increased protection of forests.

The notion that recycling of paper contributes to habitat protection and reduction of GHGs has been supported by the Intergovernmental Panel on Climate Change, which has stated[2]:*"Paper recycling is another strategy with the potential to reduce harvest levels [of timber] and promote greater carbon conservation."*

Recycling also saves on the import bill. It has been estimated that recycling of newspaper in the UK saved £216 per tonne with respect to the balance of payments[17]. According to the British Newsprint Manufacturers Association, 600,000 tonnes of recycled newsprint saved £130 million in 1994.

Potential Savings by Recycling in the UK

The figures shown in Tables 1 - 3 are derived from a US model which includes various averages and assumptions that may not always reflect specific circumstances. Thus the US model and its figures do not necessarily apply exactly to the UK situation. Indeed much of the UK figures are not readily available and more research is needed. Even paper quantities may need to be further analysed into particular categories in order to generate more precise data. If, however, the US figures are applied to the waste stream of England and Wales for those classes covered in the US study, then we can calculate that recycling and composting might save up to 4.5 million tonnes of carbon emissions per year as compared with an alternative scenario of EFW incineration[11,12] *(see Table 4*). Put another way, this is equivalent to the emissions generated by 55 billion kilometres of vehicle travel in the UK (12% of all vehicle kilometres).

One important uncertainty in the US figure is the extent to which recycling would increase storage of carbon by permitting increased tree growth in forests (and this is completely excluded from the Aylesford study). The US model (which itself links several forest carbon models) arrives at an estimate of 0.73 tonnes of carbon saved by increased storage in forest growth for each tonne of carbon recycled[18]. If we recalculate the GHG emissions eliminating all carbon savings due to

		GHG emissions saved by recycling (thousand tonnes of carbon equivalents)		
Material	Household waste (thousands of tonnes)	(a) US EPA model	(b) US EPA model, excluding forest carbon storage	(c) Using the "Aylesford" carbon saving for all paper
Newspaper	4,200	2,950	-132	17
Corrugated Boxes	115	71	-20	<1
Mixed Paper	2,000	1,044	-80	8
Aluminum Cans	44	187	187	187
Steel Cans	590	59	59	59
Glass	2,000	228	228	228
HDPE	240	155	15	15
PET	220	219	219	219
Food Waste	5,000	-292	-292	-292
Yard Waste	2,200	-160	-160	-160
Total	16,609	4,461	164	421

Table 4: GHG savings by recycling. *The table shows our estimate of the composition of household waste for certain waste streams. These figures were then used in (a) the EPA "WARM" computer model (v1.9) to generate GHG emissions for recycling/composting or incineration. Note that incineration of food and yard waste, as opposed to composting, is favourable according to this model. In (b), any forest carbon storage effect from recycling is ignored. In (c), a carbon saving of 0.004 tonnes per tonne of recycled paper(for all forms of paper) is assumed for illustration (since the Aylesford study calculated this saving). The figures above assume 100 per cent recycling, but could be reduced pro rata for lower percentages. The household waste tonnage represents around 70% of household waste.*

increased forest carbon storage *(Table 4, column (b))*, then recycling shows a slight net GHG release (as opposed to savings). This however seems a very improbable scenario (and could be avoided in any case by measures to protect forests), since it assumes that no extra growth (ie carbon storage) occurs if one reduces the harvesting rate in a forest.

In column (c), we assume a small GHG advantage to recycling (using arbitrarily the figure arrived at by the Aylesford newsprint study), and show a further advantage as compared with EFW incineration of this part of household waste.

Other Waste Streams

This section looks at some of the background considerations for other waste streams, and tries to disentangle the arguments that might be right for one type of waste, but not another.

Plastic

Incinerating plastic is a distinctly non-renewable form of energy production! Plastics are made from oil, and while the material has a high energy content, burning plastics contributes to GHG releases through carbon dioxide release. Oil is a fossil fuel, and so incineration of plastic releases carbon previously held in long-term storage in oil deposits. The US EPA study calculated that, in terms of GHG emissions, it is preferable to landfill plastic waste, locking in the carbon, rather than incinerating and releasing the carbon as carbon dioxide.

A paper from the Warren Spring Laboratory (a formerly government-funded research lab) concluded *"that despite the opportunity for substantial gains from energy recovery from waste plastics, it is still energetically more sensible to carry out materials recycling of plastics wherever it is possible to do so without energy over-intensive collection methods."*[13]

It is also worth mentioning here that much textile is derived from petrochemicals, and so similar arguments would apply to such synthetic fabrics.

Box 3: Energy from waste - landfill gas

Decomposing matter in landfill sites generates landfill gas - a mixture of methane and carbon dioxide, with other trace gases. Methane is a potent GHG, but it is possible to capture some of the methane and burn it to convert it into carbon dioxide (called flaring), reducing its potency. The heat from flaring can be used to generate electricity or supply district heating needs. Currently, many landfill sites do not capture methane, but in the future all open landfills taking biodegradable waste will have to collect and use the landfill gas. It is impossible to flare all the methane - it is generated at varying rates and over a wide area, and at low concentrations will not flare. It has been estimated that only around 40% of methane will be captured over the lifetime of a landfill in the UK[8].

Putrescibles

Putrescibles consist of organic matter which quickly rots down (e.g. food and garden waste). It can be composted or anaerobically digested, which produces a compost (assuming that it is not too badly contaminated with metals or persistent chemicals).

As with trees, carbon dioxide is incorporated into the growing plant as carbon, and is released again as carbon dioxide if incinerated, resulting in potential energy gain with no net gain or loss of GHGs. This can be regarded as a "renewable" energy form. However, if putrescible material were to be composted or anaerobically digested, then some carbon would remain fixed in the remaining organic matter (used as a soil conditioner/fertiliser), thus forming a store of carbon for some time. There is however little data on this. A US study states[18]:
"The impact of such sequestering [i.e., storage] *of carbon on global warming is not well understood. If the compost product also serves to increase vegetative growth, that additional vegetation may absorb more carbon from the air. More research is needed to evaluate these issues."*

Home composting avoids related transport emissions and provides a useful material for soil improvement, relieving pressure on peat deposits. The White Paper *Making Waste Work* set a target of 40% of homes with a garden to be composting by the year 2000[19]. But schemes involving delivery of green waste to municipal sites by individual householders are not particularly favourable in GHG terms because of transport costs[20]. The US EPA study, referred to above, estimated that it was more favourable to incinerate food scraps with energy recovery than to compost (food scraps being a renewable energy form), but that garden trimmings could be composted favourably, due to incomplete decomposition of the carbon.

Metals and glass

These materials are a significant percentage of household/municipal waste, but contain virtually no carbon and make virtually no contribution to energy production (ie they have very little "calorific value") when they are incinerated. Thus incineration of these makes no contribution to releases of GHGs (except in the related transportation) but also makes no contribution to the avoidance of fossil fuel power generation.

On the other hand, replacement of glass and metal products needs considerable inputs of energy compared with production of recycled materials. The US study on GHG emissions estimated that 4 tonnes of carbon emissions are saved for every tonne of aluminium cans recycled.

It is possible to recover iron from incineration ashes after EFW incineration and, indeed, the US greenhouse gas model does allow for some post-incineration iron recycling.

References

1. Department of the Environment, Transport and the Regions (1999). *A way with waste.* A draft waste strategy for England and Wales.

2. IPCC (1995). *Climate Change 1995: Impacts Adaptations and Mitigation of Climate Change: Scientific and Technical Analyses.* Watson, R.T. et al (eds). Published for IPCC by CUP, Cambridge, UK.

3. House of Lords Select Committee on the European Communities. *Electricity from Renewables.* Volume 1. 1999. Since coal-fired power stations are the marginal "load-following" generators, these are the first to be switched off when demand falls.

4. For example, see the Energy from Waste Association home page: http://www.efw.org.uk/

5. US Environmental Protection Agency (1998). *Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste.* The document is available on the Internet at http://www.epa.gov/epaoswer/non-hw/muncpl/ghg.htm. We have converted the figures from "US short tons" to metric tonnes of waste

6. Sound Resource Management Group Inc (1992). *Recycling Versus Incineration*. Canada, Pollution Probe Ontario. Morris, J (1996). *Recycling versus incineration: an energy conservation analysis. Journal of Hazardous Materials* 47, 277-293.

7. Ecobilan (1998). *Life cycle inventory analysis and impact assessment - Disposal options for used newspapers and magazines.* Kent, Aylesford Newsprint Limited.

8. ETSU/DTI (1996). Landfill Gas - Development Guidelines. ETSU/DTI.

9. For example, a 1998 report for the Energy From Waste Foundation on greenhouse gas emissions and waste options did not look at the savings made by recycling materials instead of manufacturing from virgin materials. *The ENDS Report (1999). Greenhouse battleground in incineration vs landfill debate.* Volume 292, 15-16.

10. The USEPA's "WARM" model is available as a spreadsheet at: http://www.epa.gov/epaoswer/non-hw/muncpl/ghg/tools.htm

11. Since the publication of the USEPA report, some emission factors have been changed. Thus there are some differences in figures generated from the "WARM" spreadsheet model (version 1.9) from the original report.

12. In order to generate this figure, some educated assumptions about classifying the waste stream components had to be made. Figures for components of the England and Wales waste stream were based on figures in *Away with Waste* (DETR, 1999) and *Re-inventing Waste* (Environment Agency/LPAC, 1998) which includes a table with a more extensive categorisation of household waste classes from several surveys of London households.
Our calculations used the default distances (32 km) for distances to the waste management sites, and we have converted the figures from "US short tons" in the original model to metric tonnes of waste. The US study estimated a 17.8% efficiency for electricity generation from incineration, and we used a 40% methane capture rate with energy recovery for landfill sites.

13. A Warren Spring Laboratory review concluded that recycling gave significant savings of energy. Ogilvie, SM (1992). *A review of the Environmental Impact of Recycling.* WSL/Department of Trade and Industry (citing work by Clark, H. and New, R. (1991). Current UK Initiatives in Plastics Recycling, Paper No W91002).

14. IIED (1996). *Towards a Sustainable Paper Cycle*. London, IIED.

15. A more detailed discussion of this can be found in a FOE briefing (1997). *Paper Recycling: Exposing the Myths.* London, Friends of the Earth.

16. BNMA (1995). *Recycle or incinerate? Summary.* BNMA.

17. Elizabeth Holtzman, Comptroller, City of New York (1992). *Fire and Ice: How Garbage Incineration Contributes to Global Warming.*

18. The US EPA model uses a projection to the year 2010. Changing the time span of the projection would change the end figure because of changes in the rates of growth (over a longer time the effect would be less).

19. DOE/WO (1995). *Making Waste Work. A strategy for sustainable waste management in England and Wales.* The Stationery Office, London.

20. European Commission, DGX1 (1996). *Cost-benefit analysis of the different municipal solid waste management systems: objectives and instruments for the year 2000.* A report by Coopers & Lybrand/CSERGE. Luxembourg, Office for Official Publications of the European Communities.

Friends of the Earth
26-28 Underwood Street
LONDON
N1 7JQ
Tel: 020 7490 1555
E-mail: info@foe.co.uk
Website: www.foe.co.uk

Printed on paper 100 per cent recycled from post-consumer waste